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Study on high-pressure CO_2 capture process

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Abstract

We report on high-pressure CO_2 capture process development with a new solvent, RH-x, developed by Research Institute of Innovative Technology for the Earth. RH-x is an aqueous solution of amine, and CO_2 capture is conducted through chemical absorption. In this study, RH-x was adopted for a test facility that has the same process configuration as the actual plant and can accommodate high-pressure conditions, and comparison results of CO_2 capture performance and energy with the existing solvent are reported. CO_2 capture performance of RH-x surpasses the existing solvents such as *N*-methyldiethanolamine (MDEA) and poly(ethylene glycol) dimethyl ether(DEPG) solutions, and the energy required for CO_2 capture is only 55 to 65% of what is required for MDEA and DEPG, indicating the superiority of RH-x.

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Keywords: *CO_2 Capture; Chemical CO_2 Solvent; High-Pressure CO_2; CO_2 Absorption*

1. Introduction

As a countermeasure for global warming and industrial use of CO_2, CO_2 capture is one of the important means. The development of CO_2 capture is in progress. In this study, wet-type absorption method was chosen, and it was

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adopted to the CO_2 capture process in a high-pressure condition, such as in fertilizer plants and hydrogen production plants, to develop a new process that can minimize the required energy.

In wet-type absorption, CO_2 as an absorption component is absorbed by solvent. As a typical CO_2 capture, there are chemical absorption methods that use chemical reactions between solvents, such as amine aqueous solution and CO_2, and physical absorption methods not associated with chemical reactions and solvents. Among chemical absorption methods conducted in relatively low-pressure conditions, CO_2 capture using amine is the most representative, and processes that use aqueous solutions such as monoethanolamine (MEA) and *N*-methyldiethanolamine (MDEA) are employed. On the other hand, as physical absorption methods used in relatively high-pressure conditions, processes that use liquids, such as methanol and DEPG (poly(ethylene glycol) dimethyl ether), are already used in commercial plants as a CO_2 capture technique in high-pressure conditions. Moreover, to improve existing solvents, they are being developed with the focus of improving amines. Mixtures, such as piperazine (PZ) and MDEA, are being studied as part of these improvements [1, 2].

In dry adsorption, an adsorption–desorption system that uses low-temperature waste heat is being investigated. Technologies that conduct CO_2 capture with even less energy (e.g., using waste heat) are also being developed [3].

Kawasaki Heavy Industries, Ltd. is developing both wet-type absorption and dry adsorption. Depending on the pressure condition, adsorption (atmospheric pressure) or absorption (high-pressure) is investigated. In absorption methods, performance of the solvent determines the performance of the process. In this study, using the solvent developed by Research Institute of Innovative Technology for the Earth (RITE), the process development was actualized.

In the existing CO_2 capture process, in order to capture CO_2, a large amount of thermal energy is required. Thus, it is not desirable from the perspective of global warming and utilization of CO_2. In other words, to capture CO_2, high absorption performance and low capture energy must be possible. In this study, the new chemical solvent for high-pressure conditions developed by RITE was used, and the results of the test jointly conducted by Kawasaki Heavy Industries, Ltd. and RITE are presented.

2. High Pressure CO_2 Capture System Experiment

RH-x, developed by RITE, is a chemical solvent for high-pressure conditions, mainly composed of amines in an aqueous solution. It is highly absorptive in high-pressure conditions (e.g., 4 MPa) and can regenerate. It exhibits high absorption and desorption in batch tests using a pressure vessel compared with MDEA aqueous solutions [4]. In this study, absorber and stripper were installed, and a new laboratory test equipment that can accommodate high pressures (4 MPa) was created. Similar to actual plants, solvent was in circulation while the CO_2 absorption operation was performed. The CO_2 capture energy was calculated from the CO_2 capture performance and required power and was compared with that of existing solvents. The absorption temperature was 30°C, absorption pressure was 4 MPa, stripping temperature was 120°C, and stripping pressure ranged from 1.6 to 3.5 MPa. The existing solvents MDEA aqueous solution (a chemical solvent) and DEPG solution (a physical solvent: average molecular weight of 240) were used for comparison. The processed gas was a mixture of CO_2 and N_2, and the flow-rate was 130 NL/min. The concentration of CO_2 was 40%vol, and the liquid–gas ratio (mass ratio) was 3 to 9. The absorber and stripper were both packed, and the inner diameter of both towers was 70.3 mm.

Fig. 1 shows a flowchart of the test facility. The test facility has absorber and stripper and circulates the solvent.

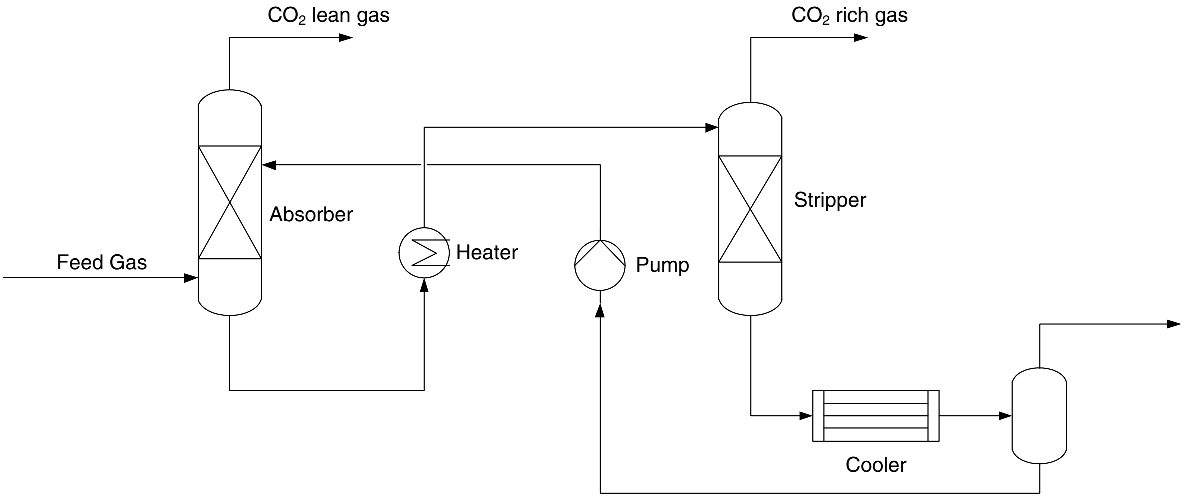

Fig. 1. Two-tower laboratory test equipment flow.

3. Results

The amount of CO_2 absorption relative to the mass liquid–gas ratio (L/G) for types of solvents, RH-x, MDEA aqueous solution, and DEPG solution were measured, and the results are shown in Fig. 2. As seen, RH-x has the highest CO_2 absorption performance. This indicates that for the same L/G, RH-x has the highest absorption performance, and to achieve a certain CO_2 capture rate, RH-x has the lowest L/G.

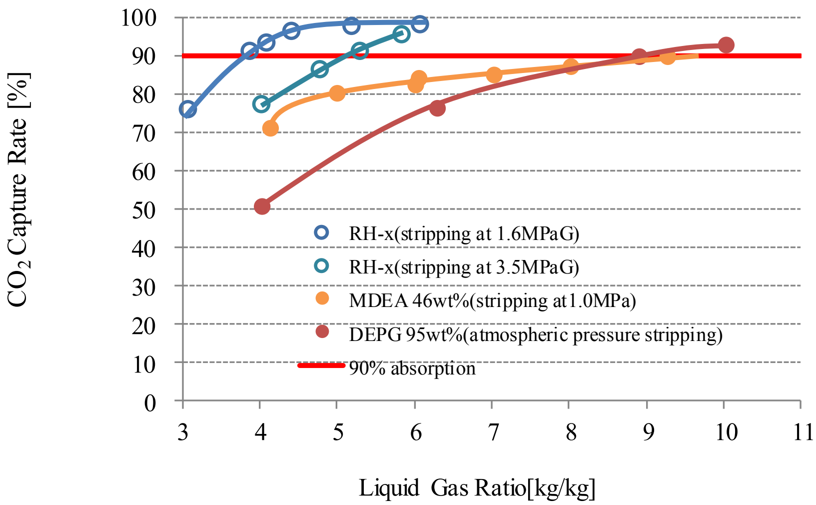

Fig. 2. Trend of CO_2 capture rate versus liquid–gas ratio.

CO_2 capture energy was the lowest in RH-x, making RH-x superior. CO_2 capture energy was calculated as the sum of thermal energy, feed pump power, and compressor power. Compressor power is the power used to compress captured CO_2 for high-pressure utilization such as CO_2 Capture and Storage (CCS). Compressor discharge pressure was assumed to be buried by CCS and set at 7.2 MPa. In other words, captured CO_2 is pressurized up to 7.2 MPa from the stripper pressure. Thermal energy was obtained by subtracting the dissipated heat (obtained from the surface temperature of the stripper measured by an infrared thermometer) from the amount of heat required.

Fig. 3 shows the CO_2 capture energy of RH-x relative to that of DEPG. The CO_2 capture energy produced during the 3.5-MPa-stripping is lower than that at 1.6 MPa. Though the CO_2 capture rate might be low, by stripping CO_2 at a higher pressure, compression energy is lowered, and as a whole, CO_2 capture energy is improved.

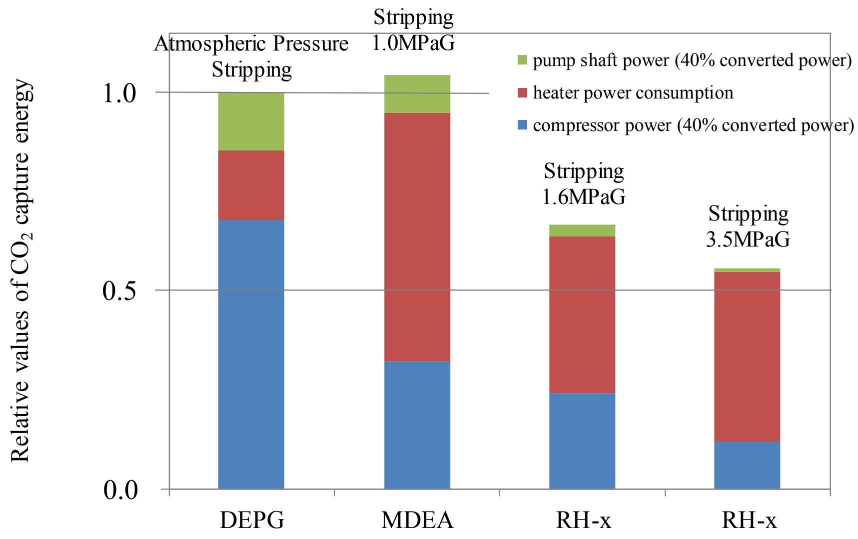

Fig. 3. Comparison of CO_2 capture energy for each solvent

Since RH-x can strip CO_2 at a high pressure, it has significant energy reduction effects when applied in high-pressure CO_2 utilization (fertilizer plants and hydrogen production process) and CCS. Furthermore, if the amount of heat required for stripping is recovered from waste heat, additional energy reduction is expected.

4. Conclusions

A CO_2 capture experiment in high-pressure conditions was conducted using the new chemical solvent RH-x. The results showed that RH-x has superior absorption performance compared with existing solvents, such as MDEA and DEPG, and that CO_2 capture energy was the lowest when assuming that CO_2 is recovered at 7.2 MPa compression.

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